TECHNICAL MEMORANDUM
WAG 2 OPERABLE UNIT 2-13
COMPREHENSIVE
BASELINE RISK ASSESSMENT STRATEGY

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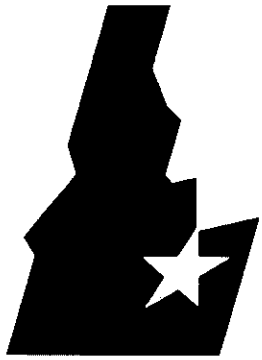

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ACRONYMS

BRA	baseline risk assessment
COC	contaminant(s) of concern
CSM	conceptual site model
ERA	ecological risk assessment
EWST	equivalent well screen thickness
FFA/CO	Federal Facility Agreement and Consent Order
FS	feasibility study
g	gram
hr	hour
in	inch
INEL	Idaho National Engineering Laboratory
IRIS	Integrated Risk Information System
m^2	meter(s) squared
m^3	meter(s) cubed
MCL	maximum contamination level
mg	milligram(s)
mrem	millirem
mr	milliroentgen
NRC	Nuclear Regulatory Commission
OU	operable unit
pCi	picocurie
PEF	particulate emission factor
PSCM	preliminary site conceptual model
RfD	reference dose
RI	remedial investigation
RME	reasonable maximum exposure
SDGA	screening data gap analysis
SLERA	screening level ecological risk assessment
SLQ	screening level quotient
TRA	test reactor area
VF	volatization factor
VOC	volatile organic compounds
WAG	waste area group

1. INTRODUCTION

This Baseline Risk Assessment (BRA) Technical Memorandum is presented as a step in the development of the comprehensive Remedial Investigation/Baseline Risk Assessment (RI/BRA) for Waste Area Group (WAG)-2 [Operable Unit (OU) 2-13] at Idaho National Engineering Laboratory (INEL). It proposes the BRA approach in order to facilitate discussion and consensus for development of the RI/FS work and ultimately the RI/BRA. Section 2 of this memorandum describes the methodology for a Screening and Data Gap Analysis (SDGA) to identify data gaps and to screen site pathways to be evaluated in the BRA. Additionally, the memorandum discusses fate and transport models (Section 3) the health-based risk assessment (Section 4), the environmental evaluation (Section 5), and the comprehensive risk assessment (Section 6).

In general, the intent of the comprehensive BRA is not to redo previous assessments, but to evaluate risk from WAG-2 as a whole rather than evaluating sites on an individual basis. However, the BRA portion of the RI/BRA will summarize the results of previously conducted risk assessments. A key component of the comprehensive BRA will be the evaluation of potential for cumulative risk from the sites in the WAG. A screening process will be implemented to focus the assessment on those sites and pathways that have potential to contribute to cumulative risk. For the sites and pathways retained for the cumulative risk assessment process, the following will be conducted as appropriate.

- Data validation and usability summary
- Cumulative fate and transport modeling
- Human health evaluation which includes:

  — Description of data collection and evaluation
  — Exposure assessment
  — Toxicity assessment
  — Risk characterization

- Ecological risk assessment.

This memorandum describes the following components of the risk assessment approach:

- Screening and data gap analysis
- Fate and transport models
- Health-based risk assessment
- Environmental evaluation
- Comprehensive risk assessment.

2. SCREENING AND DATA GAP ANALYSIS

The purpose of the SDGA is to identify risk assessment data gaps for WAG-2. These data gaps will be identified by performing cumulative risk calculations using data from previous risk evaluations. Figure 2-1 is the Preliminary Site Conceptual Model (PSCM), which illustrates the types of sites, pathways, and receptors within WAG-2. Both the sites and the pathways will be subject to screening to identify those that will be retained for the risk assessment. The results of the screening process will be presented in an SDGA technical memorandum prior to submittal of the RI/FS work plan in accordance with the RI/FS scope of work (SOW). Based on information presented in the PSCM the following scenarios and pathways will be included in the SDGA.

Scenarios:

- Occupational
- Residential intrusion

Pathways:

- Groundwater ingestion (residential scenario only)
- Inhalation of fugitive dust and volatiles
- Soil ingestion
- External exposure to radionuclides in soil
- Ingestion of home grown produce (residential scenario only).

After the screening has been completed, the PSCM will be refined and a conceptual site model (CSM) will be presented in the SDGA.

2.1 Site and Contaminant Screening

The majority of sites in WAG-2 have had the following types of risk evaluations conducted and will be screened against pathway - specific site screening criteria presented in Sections 2.2, 2.3, and 2.4.

- Remedial investigation/feasibility study (RI/FS) sites
- Interim action sites
- Track 2 sites
- Track 1 sites.

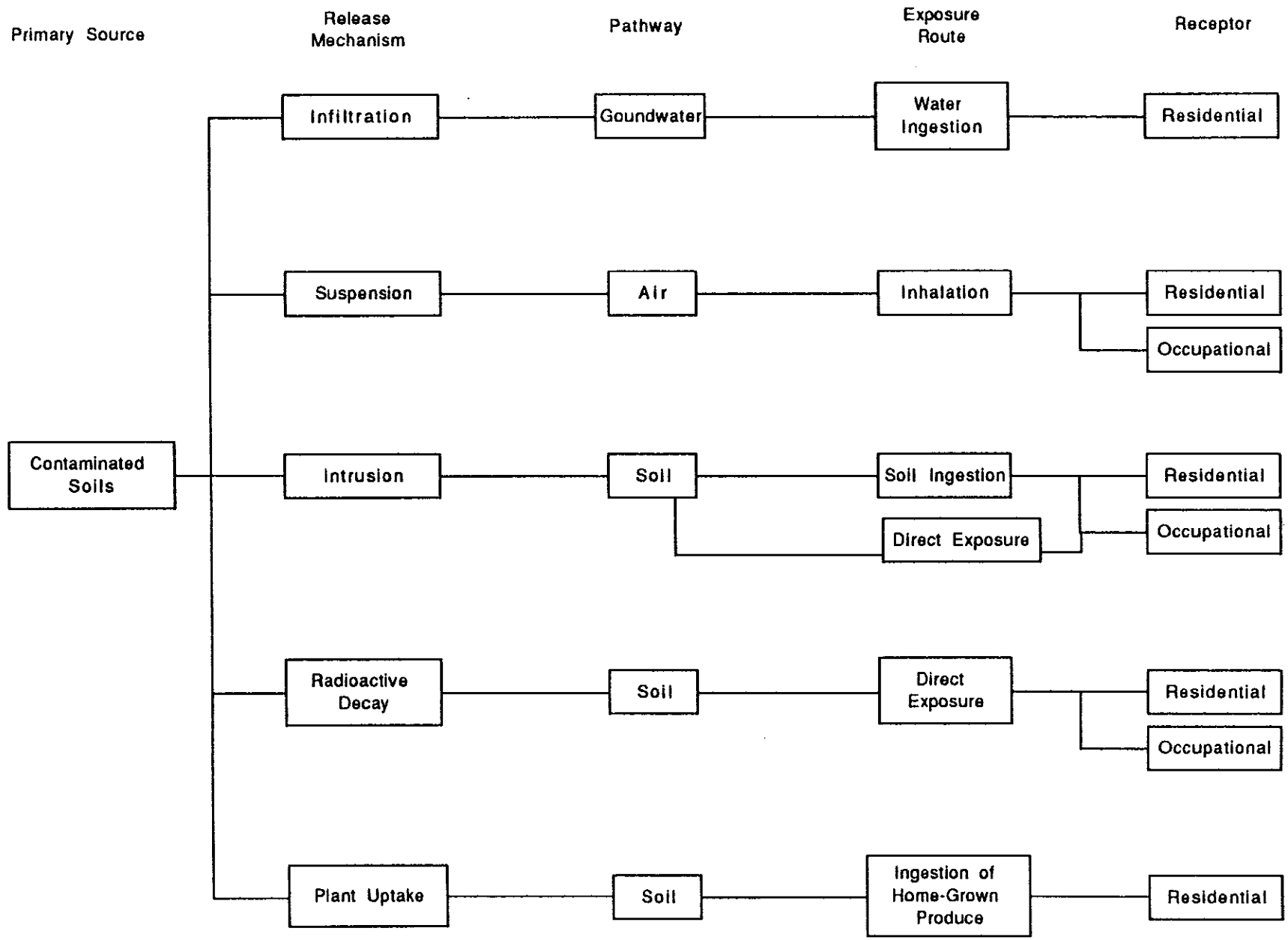

Figure 2-1. Preliminary Conceptual Site Model

A risk evaluation will be conducted for those sites that have not had a previous risk evaluation or have been remediated since the previous evaluation.

The SDGA site screening includes the following:

1. Compile information for all WAG-2 sites.

2. Identify sites that have not been evaluated.

3. Eliminate sites for which a source does not exist. These are the sites designated "no action" in the Federal Facility Agreement and Consent Order (FFA/CO) and as a result, were not assigned to an OU. The no action sites generally consist of rubble piles generated from excavation construction activities at TRA.

4. Eliminate sites for which no contamination was detected as a result of previous risk evaluation activities (e.g., Track 1 or Track 2 investigation).

5. Retain sites containing known contamination for further evaluation against the pathway screening criteria described in Sections 2.2, 2.3, and 2.4.

Once the site screening is complete, the following contaminant screening process will be performed:

1. Concentrations of all contaminants at sites that were not screened out will be compiled.

2. All contaminants that have soil concentrations less than WAG-2 baseline concentrations will be removed from further evaluation.

3. All contaminants that have a frequency of detection less than 5% and are not expected to have been disposed of at a given site will be removed from further evaluation (in accordance with EPA, 1991).

4. All radionuclides that have half-lives of less than five years will be eliminated from evaluation for the future residential-risk scenario (DOE, 1993a). This screening criteria is included because radionuclides with less than five year half-lives will pass through at least six half-lives before the residential scenario begins (30 years). The initial activity of the radionuclides will be considered to ensure that 30 years of decay will not leave more than one curie of a given radionuclide at any waste site.

5. All volatile organic compounds (VOCs) will be assumed to have completely volatilized after three years, so any VOC that was released more than three years from the date of the analysis will be eliminated from further evaluation.

All contaminants remaining after screening will be evaluated for each exposure pathway listed in Section 2.0. For all sites except the Warm Waste Pond (OU 2-10) and the North Storage Area (OU 10-06), risks and hazard quotients will be calculated using the 95% Upper Confidence Level (UCL) of the 0 to 3.1 m (10 ft) mean soil concentrations. The 95% UCL concentrations from 0 to 15 cm (6 in.) will be used for the Warm Waste Pond (OU 2-10) because intrusion into this site will be prevented by institutional controls. The North Storage Area (OU 10-06) will not be evaluated by the SDGA, but will be included in the WAG-2 Comprehensive Risk Assessment, because it is being evaluated by other studies (Haney, 1994).

2.2 Groundwater Pathway

This section discusses the methodology and assumptions for groundwater pathway screening.

2.2.1 Groundwater Pathway Methodology

To quantify risks for the future residential receptor (there is no occupational receptor for this pathway), modeling of contaminant concentrations in groundwater is required. For the groundwater pathway analysis, it is assumed that every contaminant that is not screened by the contaminant screening process (described in Section 2.1) has the potential for migration to groundwater.

The concentration of each contaminant will be estimated by summing the contaminant mass from each waste site and dividing this sum by the total mass of soil beneath WAG-2. The total mass of soil beneath WAG-2 will be calculated using the same surface area as used in the air pathway analysis (Section 2.2.1), multiplied by a depth of 3.1 m (10 ft). For the purposes of groundwater modeling, the surface area will be transformed into an equivalent rectangular area with the sides of the rectangle perpendicular and parallel to the direction of groundwater flow. This transformation is necessary because GWSCREEN, the groundwater model that will be used for this analysis, requires a rectangular site area. The receptor for groundwater ingestion will be located in the center of the downgradient edge of the WAG. The downgradient edge will be identified by comparing the orientation of the rectangular source area with the direction of groundwater flow beneath WAG-2.

The GWSCREEN model will be used to estimate contaminant concentrations at 30, 100, and 1,000 years in the future. These times were selected for several reasons. According to Track 2 guidance (DOE, 1994), the residential scenario begins at 30 years. One hundred years was selected because this is estimated to be the end of institutional control. Finally, 1,000 years was selected because it

will estimate concentrations well into the future and the 1,000 year scenario is consistent with EPA's proposed methodology for calculating soil radiological cleanup levels.

The parameters used for the GWSCREEN model are outlined in Section 3.2. A 10 cm/yr infiltration rate will be used for all sites except the cold waste pond. GWSCREEN's pond model will be used for this site.

To account for contamination originating from the perched water beneath WAG-2, contaminant concentrations in the aquifer will be taken from the Perched Water RI (OU 2-12). These concentrations will be added to the GWSCREEN concentration results to give aquifer concentrations from all sources of contamination.

After the modeling is completed, a concentration-toxicity screen will be used to screen out those contaminants that are not the predominant risk drivers. The concentration-toxicity screen will consist of the following steps:

1. Compile EPA toxicity values for both carcinogenic and noncarcinogenic contaminants.

2. Multiply exposure point concentrations by toxicity value for both carcinogenic and noncarcinogenic constituents. For carcinogens C_{gw} x SF = risk factor. For noncarcinogens C_{gw} x 1/RfD = risk factor.

3. Divide each risk factor by the total risk factor for the contaminant type (i.e., carcinogens vs. noncarcinogens). If the ratio for any contaminant is less than or equal to 0.01 then the contaminant is removed from further evaluation in accordance with EPA guidance (EPA, 1989a). A ratio of less than 0.01 will be used if there are many contaminants with a ratio of 0.01.

4. Document the contaminants that pass the concentration-toxicity screening.

2.2.2 Groundwater Pathway Assumptions

The following assumptions will be used during the groundwater screening process.

- The total mass of contaminants for all sites is available for transport.
- The receptor will be placed in the center of the downgradient edge of the WAG.
- Radioactive progeny are assumed to travel with parent radionuclides.
- All contaminants are uniformly distributed beneath TRA.

2.3 Air Pathway

This section discusses the methodology and assumptions for the air pathway analysis.

2.3.1 Air Pathway Methodology

All sites that pass the site screening criteria will be assumed to have a contaminant source. For a contaminant source to be available for release into the air pathway, one of the following criteria must be met:

- The contaminant is in the top 15 cm (6 inches [in.]) of soil for radionuclides, metals, inorganics, and semivolatiles.
- The contaminant is in the top 60 cm (2 feet [ft]) for volatile organic compounds (DOE, 1993a).

Every contaminant that is not screened by the contaminant screening process (described in Section 2.1) and which meets one of the above two source criteria will be retained for air pathway modeling. A detailed description of the model to be used is provided in Section 3.1.

Modeling of the release of contaminants to air is accomplished by different methods if the contaminant is volatile or nonvolatile. The differences arise in the calculation of the source term (the amount of contaminant released to the air). For volatiles, a soil-to-air volatilization factor (VF) will be used. The VF is used to define the relationship between the concentration of a contaminant in soil and its concentration in air. For nonvolatiles and semi-volatiles, a particulate emission factor (PEF) will be used. The PEF is an estimation of the respirable particulate emissions from wind erosion. A detailed description of these two factors is presented in INEL Track 2 (DOE, 1994) guidance. After the air concentrations are estimated, intakes may be calculated. Where applicable, the estimation of intakes from the pathway will use the equations and parameters presented in Section 4.2 for fugitive dust inhalation and volatile organic compound (VOC) inhalation.

The contamination receptor will be either a current occupational worker (who is assumed to be exposed for 25 years beginning at the present) or a hypothetical future resident (who is exposed for 30 years) depending on the time period under consideration (30, 100, or 1,000 years).

At each waste site for which air modeling will be conducted, the edges of the waste site will be defined. This definition will be based on the best available information regarding the extent of contamination at the site.

After the modeling is completed, a concentration-toxicity screen will be used to screen out those contaminants that are not the predominant risk drivers. See Section 2.2.1 for a description of the concentration-toxicity screening methodology.

2.3.2 Air Pathway Assumptions

The following assumptions will be used in the air pathway screening process.

- The contaminant mass will be released into a "box" whose area will be determined by connecting the outermost corners of the WAG-2 waste sites.

- The receptor will be assumed to spend the entire exposure duration (25 years for current occupational workers and 30 years for future residents) in the box.

2.4 Soil Pathway

This section discusses the methodology and assumptions for soil pathway screening.

2.4.1 Soil Pathway Methodology

A soil pathway screening analysis will be performed for each waste site that was retained during the site screening analysis. The following pathways will be evaluated in the soil screening analysis.

- Soil ingestion

- External exposure to radionuclides

- Consumption of homegrown produce (residential scenario only).

As with the other media analyses, a concentration-toxicity screen will be performed (see Section 2.2.1) for the soil pathways to screen out contaminants that are not risk drivers.

The risks and hazard quotients for the soil pathways will be calculated for 0, 30, 100 and 1000 years in the future according to the procedures presented in Section 4. The intake equations and parameters to be used are presented in Tables 4-7 through 4-11.

For the external exposure pathway, standard EPA protocols will be used to estimate risks for sites where a thick layer of soil is contaminated over a large area. EPA methodology will be used for these sites because the external exposure slope factors presented in EPA's Health Effects Assessment Summary Tables (HEAST)(EPA, 1993) are based on the assumption that an increase in thickness will not cause an increase in surface radiation exposure. Some radionuclide contaminated sites in WAG-2 only have thin layers of contamination. Using EPA slope factors to calculate external exposure risk at these sites would be inappropriate, so an alternate method of external exposure risk estimation will

be used where necessary.

The alternate risk calculation method to be used at sites with a thin radioactive contamination layer involves using the computer model RESRAD. RESRAD will be used to estimate the radiation exposure rate [in milliroentgen/hour (mr/hr)] a person standing at the surface would receive as a result of the site's radionuclides. The exposure rate will be converted to a dose rate [in millirem/hr (mrem/hr)] using a quality factor of one, and a risk value will be calculated using the EPA's rem to risk conversion factors (EPA, 1994). The RESRAD computer model is discussed in Section 3.3.

2.4.2 Soil Pathway Assumption

The following assumption will be used in the soil pathway analysis:

- A receptor is assumed to be present at a site for the full exposure duration (30 years for a residential receptor and 25 years for an occupational receptor).

2.5 Presentation of Risks

There are two methods of presentation for the SDGA's results presently under consideration. The first method involves developing a "fence diagram" by connecting transects passing through all of the WAG-2 waste sites. Graphs similar to Figure 2-2 will be drawn for each transect at each time period to be evaluated. The most appropriate locations for the transects is still under consideration.

The second presentation method involves drawing a map of the WAG-2 waste sites and showing the risk and hazard quotient for each pathway on a bar chart next to each waste site. This method is appropriate because the risk assessment methodology to be used for the SDGA assumes that risks and hazard quotients between the waste sites are constant. This presentation method also presents risks for the entire WAG and does not rely on selecting representative transect locations.

The selection of which presentation method is most appropriate will be made after the SDGA's preliminary risk results have been calculated.

2.6 Sensitivity Analysis

The final stage of the SDGA will be performing a sensitivity analysis for the risk and hazard quotient results. The purpose of the sensitivity analysis is to identify and rank parameters that have a significant effect on estimated risk or hazard quotients for key COCs. By doing this, quantitative information is obtained to support design of field programs and uncertainty analyses (that is, it is the more sensitive parameters that should be the focus of subsequent field programs and uncertainty analysis).

Sensitivity analysis is the process by which the response of the model to changes in input parameters can be evaluated. In a quantitative sensitivity analysis, each parameter in the model is changed by a certain amount (usually a small increment) and the response at a location, or over the model domain, is obtained. The response is calculated as the difference between some baseline value, typically a calibrated value, and the value after changing the parameter. The response is typically called a "sensitivity". By perturbing all parameters in this way, a set of sensitivities can be obtained for each parameter.

The sensitivity analysis will be performed for each parameter (or lumped parameter) for each major pathway (groundwater, air, etc.). For example, for the groundwater pathway, the sensitivity analysis might include testing source area, geometry and orientation, groundwater velocity, dispersion, etc.

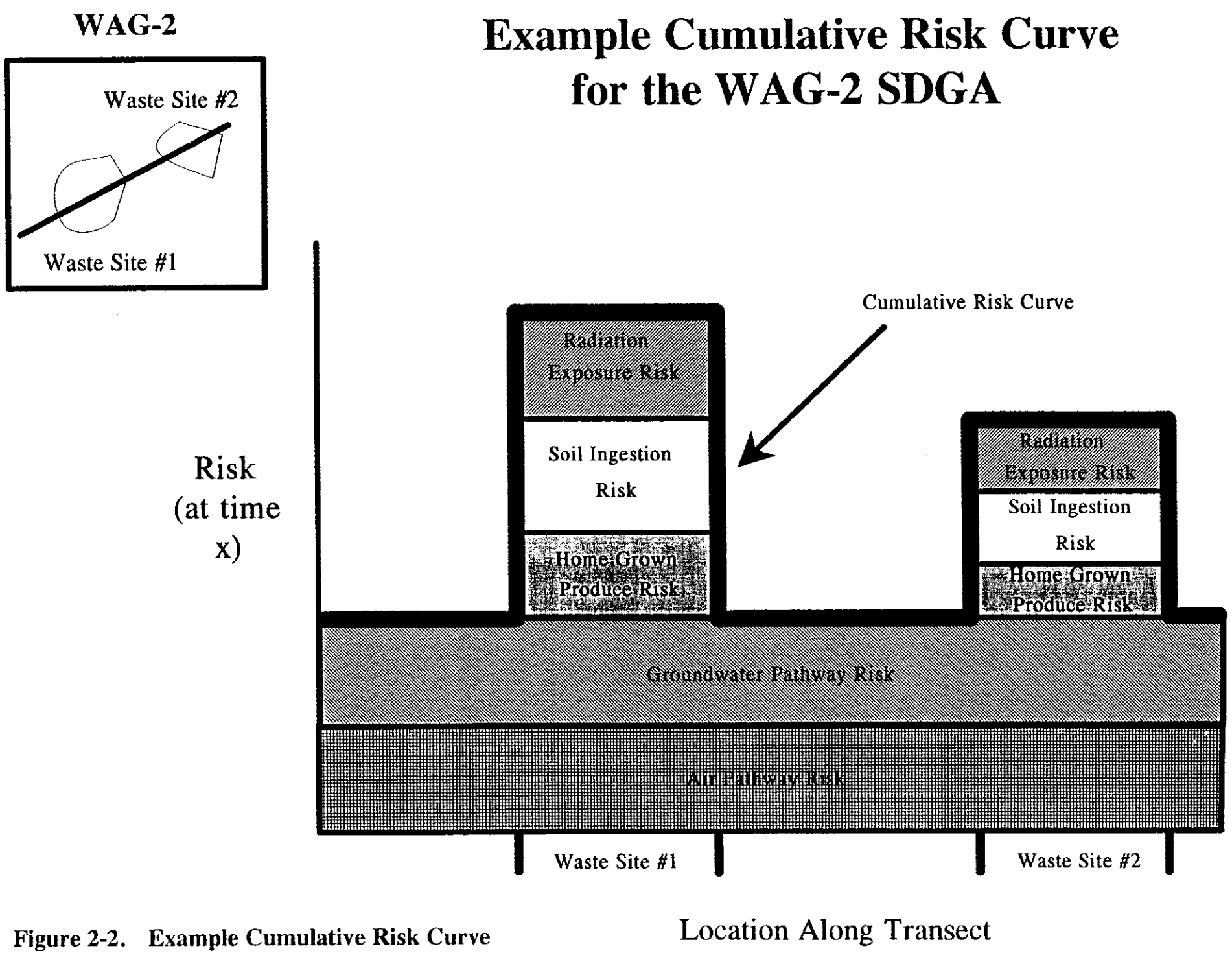

Figure 2-2. Example Cumulative Risk Curve

3. FATE AND TRANSPORT MODELS

This section presents the following models and their parameters used in the screening methodologies presented in Section 2:

- Box model
- GWSCREEN
- RESRAD.

3.1 Box Model

This subsection presents the methodology to assess contaminant air concentrations within the WAG that may result from the cumulative emissions from multiple sites within the WAG. These air concentrations may then be used to assess the cumulative health impacts (carcinogenic risk, non-carcinogenic health effects) to potential receptors in the area.

The box model (not necessarily a computer code) is often used as a screening model by government agencies to identify contaminants of concern. It has also been used as the basic workhorse in major diffusion studies of multiple sources within urban areas and has been found to perform quite well (Hanna et al. 1982).

The box model assumes that contaminant emissions within an area are uniformly mixed in a layer of depth Z_1 between the ground and the mixing height. The wind speed (u) is assumed to be constant within that layer. If emissions are assumed to be steady-state (not changing with time), then the box model equation may be written as (Hanna et al. 1982).

$$C_a = \frac{\Delta\chi \; Q_a}{Z_i \; u} \tag{1}$$

where

C_a = uniform contaminant concentration within the box [milligrams/meter^3 (mg/m^3) or picocurie (pCi/m^3)]

$\Delta\chi$ = box width [meters (m)]

Q_a = area emission rate of the contaminant [mg/m^2-grams (g)] or (pCi/m^2-g) in box.

This equation combines emissions from all sources within the box and uniformly dilutes them based on the assumed box volume and wind speed. The box width ($\Delta\chi$) may be conservatively assumed to be the longest dimension of the WAG. A conservative value for mixing height (Z_i = 2 m) and the annual average wind speed in the mixing zone [u = 3.4 m/seconds (s)] can be taken from the Track 1 guidance (DOE 1992). The contaminant emission rate (Q_a) for the box is calculated by:

$$Q_a = \frac{\Sigma\ q_g}{A_v} \qquad (2)$$

where

q_g = contaminant-specific emission rate for each individual site (mg/s or pCi/s)
A_v = area of WAG (m^2).

Individual site emission rates for a contaminant (q) are calculated using methodology similar to that used in the Track 1 guidance for fugitive and volatile emissions.

The equation for concentration of fugitive dust in the air above TRA is:

$$C_{air} = 1x10^{-9}\ R\ C_{soil} \qquad (3)$$

where

C_{air} = Contaminant concentration in the air (mg/m^3)

1×10^{-9} = Conversion from kg to mg

R = TRA respirable particulate matter (mg/m^3)

C_{soil} = Contaminant concentration in the soil (mg/kg) weighted by site area

and

$$C_{soil} = \frac{C_1A_1 + C_2A_2 + C_3A_3 + \ldots.}{A_T} \quad (4)$$

where

C_A = Contaminant soil concentration at site n (mg/kg)

A_N = Surface area of site n (m^2)

A_T = Area of TRA (m^2)

The equation for the concentration of volatiles in the air above TRA is:

$$C_{air} = \frac{(C_{soil\ 1} / VF_1)\ A_1 + (C_{soil\ 2} / VF_2)\ A_2 + \ldots}{A_T} \quad (5)$$

where

$C_{soil(n)}$ = Contaminant soil concentration at site n (mg/kg)

VF_n = Volatilization factor for site n (m^3/kg)

A_n = Surface area of site n (m^2)

A_T = Area of TRA (m^2)

After C_a is calculated, the health impacts (carcinogenic risk and noncarcinogenic hazard quotient) for individuals located within the area may be calculated using formulations of the exposure equations and parameter values discussed in Section 4.

3.2 GWSCREEN

Table 3-1 lists the contaminant and site specific parameters used in GWSCREEN. The values assigned to key parameters are discussed in this subsection.

The infiltration rate is modeled as a steady state 10 cm/year (yr) (3.9 in./yr). This is nearly 50 percent of the average annual precipitation of 22 cm/yr (8.7 in./yr) (Clawson et al. 1989). Magnuson and McElroy (1994) estimate the infiltration rate from measured interbed moisture content and fitted unsaturated hydraulic conductivity curves as 4 to 10 cm/yr (1.6 to 3.9 in./yr); 10 cm/yr is a conservative estimate.

Table 3-1. Groundwater transport parameters for WAG-2.

Parameter	Parameter value
Aquifer:	
Pore velocity	570 m/year (yr)
Longitudinal dispersivity	9 m
Transverse dispersivity	4 m
Length of well screen	15 m
Dry bulk density	1.9 g/milliliter (ml)
Porosity	0.1
K_d	Contaminant specific[a]
Unsaturated zone:	
Net infiltration	10 cm/yr
volumetric water content	0.3
Dry bulk density	1.9 g/ml
Depth to groundwater (1/10 depth to aquifer)	To be determined
K_d	Contaminant specific[a]
Soil zone:	
Soil density	1.5 g/ml
volumetric water content	0.3
Length of source parallel to flow	To be determined
Width of source perpendicular to flow	To be determined
Thickness of contaminated zone	To be determined
solubility limit	To be determined
K_d	Contaminant specific[a]
Receptor distance downgradient	To be determined
Receptor distance perpendicular to flow	To be determined
Integration time	30 yr

a. For a given contaminant, the same K_d is used for the aquifer, unsaturated zone, and soil zone.

Linear sorption coefficients (K_d) for all contaminants are assumed to be constant throughout the domain (i.e., a single value of K_d is used for the source volume, the unsaturated zone, and the aquifer). A literature search will be performed to determine acceptable values of K_d.

Dispersivities are scale-dependent parameters that account for the spreading of contamination moving through a porous medium. Values of 9 m (29.5 ft) and 4 m (13.1 ft) for longitudinal and transverse dispersivities are used. These values should be representative for the receptor distances that will be modeled.

Groundwater flow through fractured basalt is assumed to occur very rapidly relative to flow through the sedimentary interbeds. The range of the total interbed thicknesses varies from 1.5 m (4.9 ft) to 30 m (98 ft). Groundwater travel time calculations assume that a unit hydraulic gradient exists across the interbeds. Perched water at the interbeds may cause an increased gradient and reduce the travel time across the interbeds, but this effect will be neglected because of the lack of quantifiable data.

GWSCREEN requires rectangular site dimensions, so the boundaries of the model will be assigned to include the WAG-2 waste sites within a rectangular area. Setting the flow parallel to the long dimension of the site would give higher contaminant groundwater concentration results, and would therefore be conservative.

The equivalent well screen thickness (EWST) acts as both the well screen thickness and the mixing depth of the contamination. If the actual mixing depth is less than the well screen thickness, then the contaminant will be diluted in the pumping well and using an EWST equal to the well screen thickness is reasonable. If the mixing depth is larger than the well screen depth, the model will overestimate the contaminant concentrations in the well because the contaminant will spread vertically below the well screen.

3.3 RESRAD

The RESRAD computer model will be used to estimate the radiation exposure rate [in milliroentgen/hr (mr/hr)] an individual standing at the surface will receive from buried radionuclides. The exposure rate is then converted to a dose, and finally a fatal cancer risk is estimated.

The model estimates doses from all pathways that may impact a receptor (e.g. external exposure). Additionally, several critical population groups may be chosen: residents, recreational users, and occupational workers. For the BRA, the only pathway to be estimated is external exposure and the critical receptors are workers and residents.

The RESRAD code estimates the external exposure rate at 1 m (3.3 ft) above the ground surface. The model takes the depth of contamination, erosion rates, and vegetative cover into account when calculating the exposure. Exposure rates will be calculated for the principle radionuclides found at the site.

The parameters used in the RESRAD analysis will be the standard defaults used in the code with the exception of the shape of the contaminated zone and the concentrations of the principle radionuclides. According to the RESRAD documentation, only one parameter, site shape, is site dependent, all other parameters are not strongly site dependent. The area of the contaminated zone (including shape) and the principle radionuclides have not yet been determined. The parameters used for the RESRAD external exposure pathway are presented in Table 3-2.

Table 3-2. Parameter values for RESRAD code.

Parameter	Symbol	Default Value
Dose conversion factor	DCF	Nuclide dependent
Bulk density	rho	1.5 g/cm^3
Occ. and shielding factor	FO_1	0.6
Erosion rate	v	0.001 m/yr
Thickness of contaminated zone	T	To be determined
Area of contaminated zone	A	To be determined

4. HEALTH-BASED RISK ASSESSMENT

As discussed in Section 2, the SDGA will present cumulative risk calculations for WAG-2. The BRA will expand on the results of the SDGA and incorporate any data collected to address WAG-2 data gaps. This section describes the approach to the development of a BRA for WAG-2.

The approach to risk assessment is based on the Risk Assessment Guidance for Superfund (RAGS), Volume I Human Health Evaluation Manual (Part A) (EPA RAGS, 1989a, 1991), Track 2 Guidance (DOE, 1994) and Volume II Environmental Evaluation Manual (EPA RAGS, 1989b). The tasks involved in the health-based risk assessment are as follows:

- Perform data evaluation
- Conduct exposure assessment
- Conduct toxicity assessment
- Perform risk characterization.
- Conduct uncertainty analysis.

Each of these tasks are described in the following subsections.

4.1 Perform Data Evaluation

To perform the BRA, specific kinds of site characterization data (e.g., surface soil sampling and analysis) will be required to ensure complete assessment of health risks. Data collected to date by INEL will be evaluated to ascertain its appropriateness and adequacy for use in the risk assessment. In addition, data will be evaluated to ensure its usability for risk assessment generally per the Guidance for Data Useability in Risk Assessment (EPA, 1990a).

The subtasks that are performed during the data evaluation task are as follows:

- Review of available site data
- Identify data gaps, if any
- Identify contaminants detected at the site and their frequency of detection
- Test for statistical distribution of data
- Preliminary identification of potential exposure pathways
- Development of a data set for use in the risk assessment
- Identification and selection of appropriate toxicity criteria.

These subtasks will be performed during the SDGA. However, the data distributions used during the SDGA may be redeveloped for the BRA.

Contaminants identified as part of the data evaluation will be subject to :

1. Background comparison

2. A half-life evaluation

3. A concentration - toxicity screen

Contaminant concentrations will be screened against background so that only contaminants with concentrations that exceed background will be retained for further evaluation. The half-life evaluation will eliminate all radionuclides with a half-life less than 5 years for the future residential scenario. This screening is performed because the residential scenario begins at 30 years and the radionuclides with less than 5 years half-lifes will decay by at least 98.5% during that time. The concentration-toxicity screen will eliminate those contaminants which contribute a negligible risk relative to other contaminants at WAG-2. If a concentration-toxicity ratio (See Section 2.3.1) for any contaminant is less than or equal to 0.01 then the contaminant is removed from further evaluation in accordance with EPA guidance (EPA, 1989a). However, a ratio of less than 0.01 will be used if there are many contaminants with a ratio equal to 0.01.

Risk assessment guidance requires that potential risks associated with future use of the site also be quantitatively evaluated. Exposure scenarios consistent with such future use will be developed in the risk assessment. It should be noted that, in keeping with EPA guidance, future risks from the site must be evaluated on the assumption that the site may be developed for residential purposes.

4.2 Conduct Exposure Assessment

Exposure assessment consists of estimation of the magnitude, frequency, duration, and route of exposure of chemicals to humans. The magnitude of exposure is typically determined by measuring or estimating the amount of a chemical available at "exchange boundaries" (e.g., the lungs, gastrointestinal tract, or skin) during some specified time. Contact with the chemical may lead to some absorption, the magnitude of which is of great importance in calculating dose-response data for assessing health risks.

Exposure assessments typically involve the following activities:

- Identification and characterization of exposed populations
- Evaluation of exposure pathways
- Estimation of contaminant concentrations at exposure points
- Estimation of intake human rates
- Calculating intake factors

Each of these activities is described in the following subsections.

4.2.1 Identification and Characterization of Exposed Populations

The following current human populations could potentially be exposed to contaminants found at, or originating from, the site:

- **Workers** – Since WAG-2 is currently operational, workers at the site are potential receptors. If complete exposure pathways to these site workers are identified, then the risks to such site workers will be addressed.

- **Residents** – For the purposes of the BRA, residential development of the site will be considered as a potential future use of the site. Therefore, future residential use of the site will be quantitatively evaluated. Since the nearest single-family residence is more than a mile of the WAG-2, current residents will not be evaluated in this BRA.

4.2.2 Evaluation of Exposure Pathways

Once potentially exposed populations have been identified and characterized, exposure pathways can be traced from the site to these exposed populations. Each exposure pathway describes a mechanism by which a population or individual (receptor) is exposed to chemicals originating from the site. Only those exposure pathways deemed to be complete (i.e., where a plausible route of exposure can be demonstrated from the site to the receptor), will be quantitatively evaluated in the BRA (see Table 4-1 for a description of the matrix of exposure routes for WAG-2). The BRA will be based on estimates of the reasonable maximum exposure (RME) to chemicals from the site. The RME is defined as the highest exposure that is reasonably expected to occur at a site (EPA, 1989a).

Table 4-1. Matrix of exposure routes for WAG-2.

Exposure Medium/Exposure Route	Future Residential Population	Worker
Groundwater		
Ingestion	L	--
Dermal contact	L	--
Surface Water		
Ingestion	--	--
Dermal contact	--	--
Sediment		
Incidental ingestion	--	--
Dermal contact	--	--
Air		
Inhalation of vapor		
Phase chemicals		
Indoors	--	--
Outdoors	L	L
Inhalation of		
Particulates		
Indoors	--	--
Outdoors	L	L
Soil/Dust		
Incidental ingestion	L	L
Dermal contact	L	L
	L	L
Food		
Ingestion		
Fish and shellfish	--	--
Meat and game	--	--
Dairy	--	--
Eggs	--	--
Vegetables	--	--

L = lifetime exposure

-- = Exposure of this population via this route is not likely to occur.

4.2.3 Matrix of Exposure Routes for OU 2-13

Accurate estimates of chemical concentrations at points of human exposure are a prerequisite for evaluating chemical intake in potentially exposed individuals. For some media, direct measurement of chemical concentrations may not be feasible, accurate (e.g., health effects may occur below limits of detection), or cost-effective (e.g., lifetime air monitoring). Data developed during the SDGA will be used for the BRA.

4.2.4 Estimation of Human Intake Rates

Data developed during the SDGA will be used to estimate chemical concentrations in the transport medium (i.e. air, water, soil) at the point of contact with the receptor. For those media where monitoring data is not available modeled concentrations will be used. Such contact constitutes human exposure.

Human exposure is expressed in terms of intake and is defined as the amount of a chemical substance taken into the body per unit of body weight per unit time. Intake rates are calculated separately for exposures to chemicals in each environmental medium (air, groundwater, surface water, soil, and food). Then, for each exposed population, intake rates are summed for oral and inhalation exposure routes. If dermal exposure is determined to be significant, it is summed with oral exposures. All intakes are expressed in units of milligram of substance per kilogram of body weight per day (mg/kg/day).

The following paragraphs discuss the assumptions and calculations to be used to estimate intake in humans from exposure to chemicals present in air, drinking water, and soil. The magnitude of exposure to chemicals is influenced by frequency and duration of contact with these media. Also, the age of the potentially exposed individual will influence the extent of contact with these chemicals. There are three categories of parameters used to estimate intake:

- Chemical-related parameters (exposure concentrations)

- Characteristics of the exposed population (contact rate, frequency and duration of exposure, inhalation rate, soil ingestion rate, drinking water consumption rate, skin surface area, body weight)

- Averaging time.

Concentrations used in the intake calculations will be based on the 95 percent upper confidence limit of the arithmetic mean of the concentrations detected at the site or the maximum detected concentration whichever is the least, as recommended in the EPA and Track 2 guidance (DOE, 1994). However, if the data are found to be log-normally distributed, then the arithmetic mean of the transformed data will be used in the intake calculations in accordance with the Supplemental Guidance to RAGS: Calculating the Concentration Term (EPA, 1992c).

Contact rate reflects the amount of impacted medium (air, water, soil) to which an individual is exposed per unit time or event. EPA guidance (EPA 1989b) recommends that if statistical data are available, the 95 percentile values be used. If several parameters are used in the calculation, the combined result should approximate the 95 percentile value. Exposure frequency, duration, and intake parameters will be consistent with EPA guidance (1990b) and are presented in Tables 4.2 through 4.11.

4.2.5 Calculating Intake Factors

Exposure frequencies and durations to be used for calculating external radiation exposure will be consistent with values used to calculate intake factors. Exposure point concentrations will be used with these parameters to obtain pathway-specific intakes. The equation for intake in terms of mg/kg/day is:

$$\text{Intake} = \frac{\text{chemical conc.x contact rate x exposure frequency x exposure duration}}{\text{body weight x averaging time}} \quad (5)$$

The corresponding units for the equation follow.

$$\text{mg/kg/day} = \frac{\text{mg/volume} \times \text{volume/day} \times \text{day/year} \times \text{year}}{\text{kg} \times \text{day}} \quad (6)$$

4.3 Conduct Toxicity Assessment

Toxicity assessment is the process of characterizing the relationship between the dose or intake of a substance and the incidence of an adverse effect in the exposed population. Toxicity assessments evaluate results from studies with laboratory animals, or from human epidemiological studies. These evaluations are used to extrapolate from high levels of exposure where adverse effects are known to occur to low levels of environmental exposures where effects can only be predicted based on statistical probabilities. The results of these extrapolations are used to establish quantitative indicators of toxicity.

Health risks from all routes of exposure will be characterized by combining the chemical intake information with numerical indicators of toxicity. These health-protective toxicity criteria are obtained through EPA-developed reference doses (RfDs) or slope factors (SFs). It is assumed that health-based toxicity criteria are available for all contaminants of concern (COCs).

Table 4-2. Inhalation of particulates for on-site worker.

$$\text{Intake factor} = \frac{IR \times ET \times EF \times ED}{BW \times AT \times PEF}$$

	Parameter	RME
IR =	Inhalation rate (m^3/day)	20
EF =	Exposure frequency (day/yr)	250
ED =	Exposure duration (yr)	25
PEF =	Particulate emission factor	To be determined
BW =	Body weight (kg)	70
AT =	Averaging time (day)	
	Noncarcinogenic	9,125
	Carcinogenic	25,550

Table 4-3. Inhalation of volatiles for on-site worker.

$$\text{Intake factor} = \frac{IR \times ET \times EF \times ED}{BW \times AT \times VF}$$

	Parameter	RME
IR =	Inhalation rate (m^3/day)	20
EF =	Exposure frequency (day/yr)	250
ED =	Exposure duration (yr)	25
VF =	Volatilization factor	Chemical specific
BW =	Body weight (kg)	70
AT =	Averaging time (day)	
	Noncarcinogenic	9,125
	Carcinogenic	25,550

Table 4-4. Inhalation of particulates for hypothetical future on-site resident.

$$\text{Intake Factor} = \frac{IR \times ET \times EF \times ED}{BW \times AT \times PEF}$$

	Parameter	RME
IR =	Inhalation rate (m^3/day)	20
EF =	Exposure frequency (days/yr)	350
ED =	Exposure duration (yr)	30
PEF =	Particulate emission factor	To be determined
BW =	Body weight (kg)	70
AT =	Averaging time (day) Noncarcinogenic Carcinogenic	10,950 25,550

Table 4-5. Inhalation of volatiles for hypothetical future on-site resident.

$$\text{Intake factor} = \frac{IR \times ET \times EF \times ED}{BW \times AT \times VF}$$

	Parameter	RME
IR =	Inhalation rate (m^3/day)	20
EF =	Exposure frequency (days/yr)	350
ED =	Exposure duration (yr)	30
VF =	Volatilization factor	Chemical specific
BW =	Body weight (kg)	70
AT =	Averaging time (day) Noncarcinogenic Carcinogenic	10,950 25,550

Table 4-6. Groundwater ingestion for hypothetical future on-site resident.

$$\text{Intake factor} = \frac{IR \times EF \times ED}{BW \times AT}$$

	Parameter	RME
IR :	Intake rate (l/day)	2
EF :	Exposure frequency (day/yr)	350
ED:	Exposure duration (yr)	30
BW:	Body weight (kg)	70
AT:	Averaging time (day)	
	Noncarcinogenic	10,950
	Carcinogenic	25,550

Table 4-7. Soil ingestion for on-site worker.

$$\text{Intake factor} = \frac{IR \times EF \times ED \times CF}{BW \times AT}$$

	Parameter	RME
IR =	Ingestion rate (mg/day)	50
EF =	Exposure frequency (day/yr)	250
ED =	Exposure duration (yr)	25
CF =	Conversion factor (kg/mg)	10^{-6}
BW =	Body weight (kg)	70
AT =	Averaging time (day)	
	Noncarcinogenic	9,125
	Carcinogenic	25,550

Table 4-8. Soil ingestion for hypothetical future on-site resident (adult and child).

Intake factor = $\frac{IR \times EF \times ED \times CF}{BW \times AT}$

Parameter		RME	
		Adult	Child
IR =	Ingestion rate (mg/day)	100	200
EF =	Exposure frequency (day/yr)	350	350
ED =	Exposure duration (yr)	24	6
CF =	Conversion factor (kg/mg)	10^{-6}	10^{-6}
BW =	Body weight (kg)	70	15
AT =	Averaging time (day)		
	Noncarcinogenic	10,950	2,190
	Carcinogenic	25,550	25,550

Table 4-9. External exposure for on-site workers.

Intake factor = ET x EF x ED x CF

Parameter		
ET =	Exposure time (hr/day)	8
EF =	Exposure frequency (day/yr)	250
ED =	Exposure duration (yr)	25
CF =	Conversion factor (yr/hr)	1.14×10^{-4}

Table 4-10. External exposure for future on-site resident.

Intake factor = ET x EF x ED x CF		
	Parameter	RME
ET =	Exposure time (hr/day)	24
EF =	Exposure frequency (day/yr)	350
ED =	Exposure duration (yr)	30
CF =	Conversion factor (kg/mg)	1.14×10^{-4}

Table 4-11. Home grown produce ingestion for hypothetical future on-site resident.

Intake factor = $\frac{IR \times EF \times ED \times CF}{BW \times AT}$		
	Parameter	RME
IR =	Ingestion rate (g/day)	120
EF =	Exposure frequency (day/yr)	350
ED =	Exposure duration (yr)	24
CF =	Conversion factor (kg/mg)	10^{-6}
BW =	Body weight (kg)	70
AT =	Averaging time (day)	
	Noncarcinogenic	10,950
	Carcinogenic	25,550

The BRA will include a toxicological profile for each COC identified at the site. These profiles will discuss:

- Acute and chronic toxic effects of these chemicals in humans;
- Environmental fate and transport (e.g., degradation process, products, mobility within each medium, and potential means of transport from one medium to another);
- Maximum contamination levels (MCLs) and other health-protective criteria.

Toxic effects are divided into two classes for purposes of establishing quantitative indicators of toxicity: noncarcinogens and potential carcinogens. Each is discussed in the following subsections.

4.3.1 Toxicity Indicators for Noncarcinogens

In accordance with EPA guidance, the preferred numerical indicators of toxicity will be EPA-derived RfDs. Reference doses for chemicals considered in the risk assessment will be obtained from the EPA's Integrated Risk Information System (IRIS) database. The RfD is based on the assumption that thresholds exist for certain noncancerous toxic effects such as cellular necrosis, but may not exist for other toxic effects such as cancer. The RfD is an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime of exposure.

4.3.2 Toxicity Indicators for Potential Carcinogens

Evidence of carcinogenicity of a chemical comes from two sources: life-time studies with laboratory animals, and human studies where excess cancer risk is associated with exposure to the carcinogen chemical. Unless evidence to the contrary exists, if a carcinogenic response occurs at the exposure levels studied, it is assumed that a similar response will occur at all lower doses. Exposure to any level of a carcinogen is therefore considered to have a finite risk of inducing cancer (i.e. zero risk is associated with zero exposure).

Since risks at low levels of exposure cannot be quantified directly from either animal or epidemiological studies, mathematical models are used to extrapolate from high to low doses. The linearized multi-stage model procedure for low-dose extrapolation is recommended by the EPA (EPA, 1986). Use of the linearized multi-stage model leads to a plausible upper-bound estimate of risk. The linearized multi-stage model incorporates procedures for estimating the largest possible slope at low doses that is consistent with the experimental dose-response data (use of a large slope tends to produce a higher estimate of cancer risk). The animal data used for extrapolation is taken from the most sensitive species studied, based on the assumption that man is at least as sensitive as the most sensitive animal species. The risk estimates made with this model should be regarded as health-protective representing the most plausible upper limit of risk. That is, the true risk is not likely to be higher than the estimate and, most likely will be lower.

Numerical estimates of cancer potency are presented as SFs. Under the assumption of dose-response linearity at low doses, the SF defines the cancer risk due to continuous life-time exposure to one unit of carcinogen (in units of risk per mg/kg/day). Cancer risk assessment in this risk assessment involves calculating upper-bound estimates. Individual cancer risk will be calculated as the product of exposure to a chemical (in mg/kg/day) and the SF for that chemical, (in mg/kg/day)$^{-1}$. Cancer risks from exposure to multiple carcinogens and multiple pathways will be assumed to be additive, based on EPA carcinogen risk assessment guidelines (EPA, 1986).

4.4 Perform Risk Characterization

The characterization of risks involves combining the results of the toxicity and exposure assessments to provide numerical estimates of health risk. These estimates are comparisons of exposure levels with appropriate toxicity criteria or estimates of the lifetime cancer risks associated with a particular intake. Risk characterization also considers the nature and weight of evidence supporting these risk estimates, as well as the magnitude of uncertainty surrounding such estimates.

The following calculation is used to obtain numerical estimates of lifetime cancer risks:

$$Risk = Intake \times SF \quad (8)$$

where

Risk = potential cancer risk adjusted for lifetime exposure (unitless)
SF = slope factor $(mg/kg/day)^{-1}$
Intake = chemical intake (mg/kg/day).

To obtain an estimate of total risk from all carcinogens at the site, cancer risks will be summed across all exposure pathways identified in the risk assessment.

For EPA-developed RfDs, noncancer risks will be evaluated by calculating a hazard index. The hazard index is the ratio of the intake rate to the RfD (developed by the EPA), as follows:

$$HQ = Intake / RfD \quad (9)$$

where

HQ = Hazard Quotient
Intake = Chemical intake (mg/kg/day)
RfD = Reference Dose (mg/kg/day).

Hazard quotients will be summed across exposure pathways.

4.5 Conduct Uncertainty Analysis

The characterization of uncertainty is an important component of the BRA process. According to EPA's Guidance on Risk Characterization for Risk Managers and Risk Assessors, point estimates of risk "do not fully convey the range of information considered and used in developing the assessment." To provide information about the uncertainties associated with the RME estimate, a qualitative or semi-quantitative uncertainty analysis will be performed after the SDGA. The qualitative uncertainty analysis will examine the components of the BRA and will assess the effect of the uncertainty involved with each. The analysis will assess the effect of over or under estimating the risk. The results of this analysis will be presented in tabular format.

5. ECOLOGICAL RISK ASSESSMENT

Ecological risk assessment (ERA) is the evaluation of the likelihood that undesirable ecological effects may occur or are occurring as a result of exposure to one or more stressors (where "stressor" refers to any physical, chemical, or biological entity that can induce an adverse effect) (EPA, 1992). The process of an ERA involves identifying the adverse effects to be addressed using mathematical, statistical, or qualitative techniques and models to evaluate the relationship between the contamination or activities and their effects.

The goals of ERA, as stated in the DOE framework (DOE 1993b), of the WAG-2-wide ERA are to:

•Contribute to remediation of the site by providing information and analysis which will aid in the remedial decision-making process

•Inform risk managers and the public of the magnitude and significance of ecological risk at the site

•Enhance the credibility of the entire BRA by ensuring that nonhuman receptors are protected from potential adverse effects of the site.

The WAG-2 ERA will be accomplished in two phases. The first phase was the screening-level ERA (SLERA) which will be followed by a more detailed ERA as needed. The WAG-2 SLERA is being transmitted as a separate document under the same cover letter. The draft SLERA for WAG-2 has been completed (Hampton et al., 1994). The SLERA endpoints were not attained [i.e., all screening level quotients (SLQs) were not less than 1]. In addition, all WAG-2 sites were not evaluated. Consequently, no final management decisions regarding actual risk could be made using the SLERA.

The WAG-2 SLERA determined that it will be necessary to incorporate the additional site contamination data as data collection is finalized. For those functional groups determined to be at potential risk as a result of the screening, the first step would be to determine if it is possible to use the site specific data available from sources at INEL for the functional group parameters. A more detailed discussion of the sites that are driving the analysis should be included potentially using a limited spatial analysis. The WAG-2 SLERA also concluded that use of site specific data, instead of conservative assumptions, would allow a more realistic interpretation of the potential risk.

5.1 Problem Formulation

Problem formulation is the essential scoping component in the ERA process. The main feature of problem formulation is a preliminary evaluation consisting of the identification of relevant policy goals, a description of target ecosystems and their components, and identification of potential stressors, pathways, and ecological effects. The preliminary evaluation leads to selection of ecological endpoints appropriate for the site. Since ecosystems are too diverse to allow analysis of every receptor, specific receptors and endpoints are selected to determine ecological effects. Problem formulation concludes with the conceptual model for the WAG-2. The conceptual model summarizes the preliminary evaluation and endpoint selection by providing a set of working hypotheses to account for the potential ecological impacts of stressors at the site (DOE, 1993b). The majority of the WAG-2 problem formulation has been prepared for the SLERA and can be incorporated and enhanced into the WAG-2 ERA.

The problem formulation section also contains data acquisition, verification, and monitoring where appropriate. The WAG-2 SLERA determined that it will be necessary to incorporate the additional site contamination data as data collection is finalized. This would be performed during the ERA. The verification and monitoring program should be tied to the measurement endpoints established for WAG-2. Data acquisition should also be integrated with the RI/FS site characterization. For example, there may be a need to conduct media sampling from habitats adjacent to source areas, and information on body burdens or tissue concentrations of contaminants may be required.

5.2 Risk Analysis

The analysis component of ERA involves the technical evaluation of exposure and effects. Analysis of exposure and effects is based on the ecological endpoints and conceptual model derived during the problem formulation component. The elements of the exposure assessment include (i.e., DOE, 1993a or 1993b):

- Stressor characterization: determination of the distribution and concentrations of contaminants
- Receptor characterization: analysis of the spatial and temporal distribution of selected endpoint species, and factors affecting their exposure to contaminants (e.g., activity patterns)
- Exposure analysis: analysis of factors affecting bioavailability, uptake, and pharmacokinetics of contaminants
- Exposure profile: quantification of exposure point concentrations or doses.

The sources of contaminant data for the exposure assessment include the results of direct sampling efforts and fate and transport models. The model used for WAG-2 will be site-specific and will incorporate applicable WAG-2 data as determined in the SLERA.

5.3 Risk Characterization

The risk characterization component of ERA involves an integration of the results of the analysis phase for the following purposes:

- To identify risks
- To evaluate the uncertainties of the ERA
- To summarize and describe the significance of the risks.

The two main steps of risk characterization are risk estimation and risk description. Risk estimation uses integration and an uncertainty analysis. Integration is a comparison of the exposure and stressor-response profiles developed in the analysis phase. The uncertainty analysis is an identification and quantification (if possible) of uncertainties in the ERA. The risk characterization section also presents the results of the assessment as input to the risk management process.

6. COMPREHENSIVE RISK ASSESSMENT

The comprehensive RI/BRA addresses all sites within the WAG (including those screened out during the SDGA) and presents the results of the cumulative risk assessment. The comprehensive (WAG-wide) risk assessment will be performed in accordance with appropriate guidance. The comprehensive risk assessment will be developed in a phased approach. This phased approach consists of the following phase.

1. Develop BRA Technical Memorandum
2. Conduct SDGA
3. Evaluate data gaps
4. Develop a work plan
5. Conduct RI/BRA.

This technical memorandum was developed as phase 1 of the approach. The methodology for phase 2 is presented in this technical memorandum in sections 2 and 3. Phase 2 will assess the cumulative risks associated with the screened sites, and identify data gaps. Phase 3 will evaluate any data gaps to determine possible solutions. After data gaps have been identified the WAG-2 RI/BRA Work Plan will be developed. Finally, the comprehensive RI/BRA will be conducted.

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